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Environmental Affairs Department

August 4, 1993

Arthur H. Fieser, Ph.D., P.E.
Chief - Engineering Section
Allegheny County Health Department
Bureau of Environmental Quality
301 Thirty-Ninth Street
Pittsburgh, PA 15201

Dear Dr. Fieser:

Re: Requirements of Title 25 Pennsylvania Code
       NOx Continuous Emissions Monitoring

U. S. Steel is pleased to submit, for BEQ review, a protocol to develop an enhanced
monitoring program to measure NOx emissions for the following sources:

        -- Edgar Thomson: Riley Boilers No. 1, 2, and 3
        -- Clairton Works: Boilers No. 1 and 2; Battery "B"

The attached protocol defines the testing and statistical analysis that will be
conducted to identify the operating parameters that demonstrate a "definite and
consistent relationship" to NOx emission rates and will, therefore, provide
representative and accurate NOx emission data. Subsequent to testing and data
analysis, an Enhanced Monitoring Plan (EMP) will be prepared and submitted to the
BEQ for review and approval.

I will contact you and E. J. Taylor within the next two weeks to discuss the protocol.
However, please contact me (433-5918) if you have any questions in the meantime.

                                 Very truly yours,

                                 L. E. Guevara

8/5 TO EJT for review

                                 Lorraine E. Guevara

LEG/d(1.016)
Attachment

cc: E. J. Taylor - w/att.

Enhanced Monitoring Protocol for NOx Emissions

Edgar Thomson Boilers (1, 2, and 3)

and Clairton Boilers (1 and 2) and Battery B

Prepared for

Allegheny County Health Department

Bureau of Environmental Quality

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Prepared by

U. S. Steel

Pittsburgh, PA

and

Energy Systems Associates

Pittsburgh, PA

July 1993

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1.0 INTRODUCTION

This protocol defines the testing and data analysis that will be conducted to develop the enhanced monitoring program which will predict and report NO_x emissions for U. S. Steel's Edgar Thomson Boilers No. 1, 2, and 3, Clairton Boilers No. 1 and 2, and Clairton Battery B. The testing and data analysis will identify the operating parameters that have a definite and consistent relationship to NO_x emissions and would, therefore, provide accurate NO_x emission data when monitored.

Subsequent to testing and data analysis, an Enhanced Monitoring Plan (EMP) will be submitted to the Allegheny County Bureau of Environmental Quality (BEQ) for review and approval. The EMP will include:

(1)   a description of the specific operating parameters to be monitored and the relationship between those parameters and NO_x emissions.

(2)   data and information used to identify or mathematically compute the relationship between NO_x emission rates and those operating conditions.

(3)   a description of how the operating parameters are and will be monitored, the QA/QC procedures to be employed to assure representative and accurate monitoring, and the reportage format.

U. S. Steel has contracted with Energy Systems Associates (ESA), a qualified combustion consultant with specific expertise in NO_x formation, to conduct the testing and analysis, and to assist in the development of the EMP.

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2.0 WORK SCOPE

2.1 Evaluation of Operating Parameters

The operating parameters currently available at each unit will be reviewed to provide data for accurate prediction of NO_x emissions. Initial site visits have been made to become familiar with boiler and battery equipment, and operational data measurement systems. Additional site visits will be made to obtain more specific information. Knowledge of the Clairton monitoring techniques, as well as those of the VAX computer at Edgar Thompson (ET) will be obtained to assure workability of the NO_x prediction plan. Ability to integrate the NO_x prediction plan formula into the VAX computer will be studied to enable real-time or hourly prediction of NO_x emissions.

Operating practices and reportable control settings or parametric measure shall include but not be limited to:

Boilers

- Load (lb steam/hour)
- Reported flue gas O_2
- Degree of staging
- Fuel flow pressure and temperature (°F)
- Flow percentage of mixed in natural gas
- Air flow temperature (°F)
- Steam temperature (°F/psig)
- Stack and ambient temperature (°F)
- Feedwater temperature (°F and percent B.D.)
- Observed boiler wall deposits

Coke Oven Heating

- Percent output
- Reported flue gas O_2 (estimated leakage)

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- Degree of staging
- Fuel composition, SpGv heating content
- Heating values, Wobbe Index
- Underfiring pressure (inches $H_2^{\wedge}O$)
- Percent mix of fuels and temperature (°F)
- Waste heat (canal flue temperature, °F)
- Flue gas stack draft
- Oven profile temperature (°F)
- Ambient temperature (°F)
- Natural gas mix flow
- COG pressure/volume
- Observed burner tube deposits

NO_x emissions are known to be parametrically influenced by excess combustion air (flue gas O_2), degree of staging load, percent of capacity, fuel mixture, (% BFG:COG:NG) and chemical composition of each, fuel nitrogen content (tars/ammonia/amines) and furnace conditions (e.g., boiler wall deposits). Therefore, it will be necessary to conduct a number of flue gas emissions tests with certain of these parameters fixed while others are intentionally altered. This will provide a monitored variation so that the potential relationship of NO_x emissions to parametric values can be graphically charted and reviewed for statistical significance.

ESA will review unit load profiles and characteristics to determine optimum test intervals so that statistically significant quantities of test points are achieved. The objective of the eventual EMP is to develop meaningful relationships between the dependent variable, NO_x, and those various boiler parameters that will have been found to be statistically significant.

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2.2   Perform Emissions Testing

ESA will conduct NO_x emission characterization tests on Boilers 1 and 2 and Battery B coke oven at Clairton. Edgar Thompson Boilers 1, 2, and 3 will be checked to assure that they are in fact, as is expected, similar to one another in combustion characteristics and NO_x emissions. Thus, one boiler at Edgar Thompson can be selected as representative of the other two for NO_x emission characterization testing.

The objectives of the testing are to document NO_x emissions trends and the boiler or coke oven operating practices and control settings that can be shown parametrically to affect the rate of NO_x emissions. ESA will follow EPA Source Sampling Method 7E for determination of nitrogen oxide emissions, together with other appropriately simplified EPA methods, to determine concentrations of NO, O_2, and CO_2 in exit flue gases. (Laboratory sampling equipment and procedure references are provided in Section 3.0).

Sampling test port locations will be those normally used and established in accordance with EPA Method 1. Gas mixture, chemical composition, and Wobbe Index heating value will be those regularly measured and reported by each unit at each plant. The F-factor will be calculated from the fuel analyses and heat input ratios in accordance with 40 CFR 60, Appendix A, Method 19.

2.3   Data Analysis

Regression analysis will be used to determine which parameters are significant in predicting NO_x emissions. The combustion consultant will confer with key operating personnel to preview historical parametric data such as O_2, percent load, fuel mixes, temperatures, and Wobbe Index as obtained from existing monitoring. This review and preliminary analysis should guide and expedite the data analysis task for complications

such as discontinuity in parametric correlations, nonlinear correlations, or data scatter such as in Wobbe Index readings.

Data collected from the emissions tests will be entered to a multiple regression analysis to select the statistically significant variables.

The objective of the EMP is to identify strong relationships between NO_x (the dependent variable) and those parameters (independent variables) found to be statistically significant. The basic form of the multiple regression equation is a subset of the following:

$$NO_x = B_0 + B_1 \text{ (air flow)} + B_2 \text{ (boiler temp)} + ...$$

where: B_0, B_1, B_2, etc. are operating parameters.

Multiple regression analyses will be conducted using a Lotus statistical analysis system software. The stepwise procedure will be used to first determine the parameters that are significant in predicting NO_x emissions. Analysis will begin with the forward-selection technique. Forward-selection begins with the best one-variable model and progressively adds variables that are found to be statistically significant. Variables are added one by one until no remaining variables meet the selection criteria for entry into the model. The backward-elimination technique begins by calculating statistics for a model, including all of the independent variables. Then variables are deleted one by one until all the remaining variables are considered statistically significant. The process ends when none of the variables outside the model are statistically significant.

Finally, the "best fit" variables are determined and equations for prediction of NO_x emissions evolve. Different or discontinuous equations (or simply stated single emissions rates) can result from a discontinuity in operational significance of certain parameters to the generation of emissions.

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2.4 Validation of NO$_x$ Prediction Model

Statistical procedures are used to compare actual NO$_x$ values, the predicted values and the residuals which are summarized in frequency distribution tables. Here, it is possible to demonstrate how well the predicted NO$_x$ values compare to the actual NO$_x$ values obtained during the emissions testing program. A scatter plot will depict actual NO$_x$ values versus predicted NO$_x$. The difference between actual and the plotted prediction curve are termed "residuals." The residuals are plotted as a frequency distribution about zero error or prediction and can then be calculated for expected maximum error and for standard deviation. The accuracy goal is 0.95 when expressed as r^2, the coefficient of determination defining the proportion of conformance to a linear equation.

To help define key statistical concepts from the methodology of regression analysis, the following list is offered.

Scatter Plot - A picture of bivariate numerical data in which each observation (x, y) is represented as a point located with respect to a horizontal x axis and a vertical y axis.

Spearman's correlation coefficient - Another measure of how strongly x and y values in a bivariate numerical data set are related. It is based on the ranks of the x and y observations and will identify strong nonlinear as well as linear relationships.

Principle of least squares - A general principle used to select a line that summarizes an approximate linear relationship between a dependent variable y and an independent (or predictor) variable x. The sum of squared vertical deviations from a line to the points in the scatter plot is used to measure how well the line fits the data. The least squares line is the line with the smallest sum of squared deviations.

Residual sum of squares (SSResid) The sum of squares of residuals (vertical deviations from the least squares line), which measures the variations in observed y values that cannot be attributed to an approximate linear relationship between x and y.

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